



Advanced Blade Technology Developments

Presented by
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The Technology Transfer Conduit: From Enabling Research to Commercial Product

Commercial
Product

LWST Contracts



Research Contracts and Testing



Enabling Research – Tools, Information, and Concepts



Blade/Rotor LWST Goals

2002 --- Identified Technologies to Meet LWST Cost Goals

Blade-related Technologies

- Advanced rotors and controls -15% \pm 7%
- Manufacturing improvements -7% \pm 3%
- TOTAL ESTIMATED REDUCTIONS for all technologies -44% \pm 32%**

2003-04 ---Transformed into Specific TIO's and into Tracking System

Advanced (Enlarged Rotor)

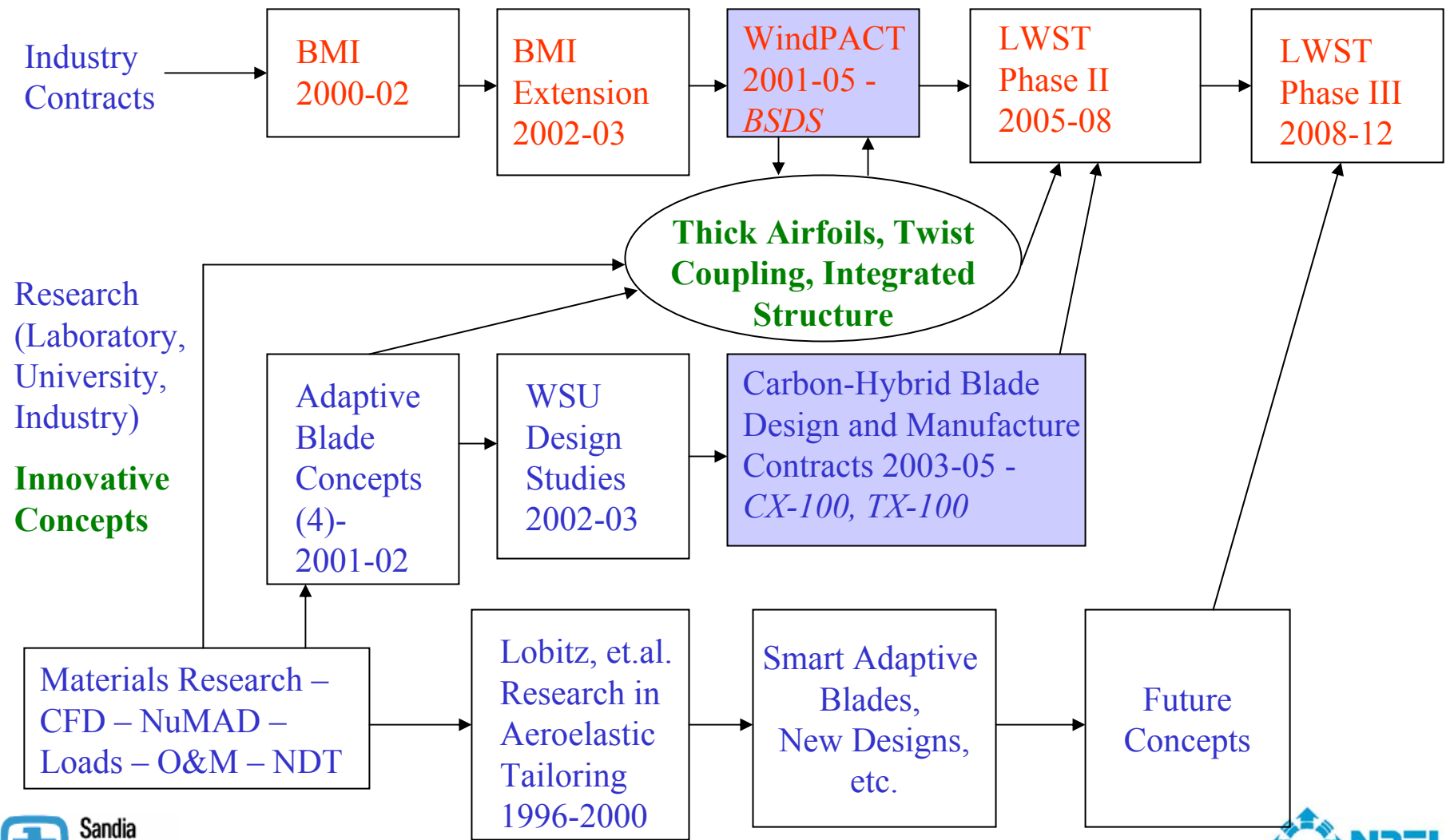
- **Advanced Materials**
- **Changed/improved structural/aero design**
- **Active controls**
- **Passive controls**
- **Higher tip speed ratios/lower acoustics**

Manufacturing

- **Manufacturing methods**
- **Manufacturing mark-ups**
- **Lower margins**



Blade Developments through Research and Industry Contracts



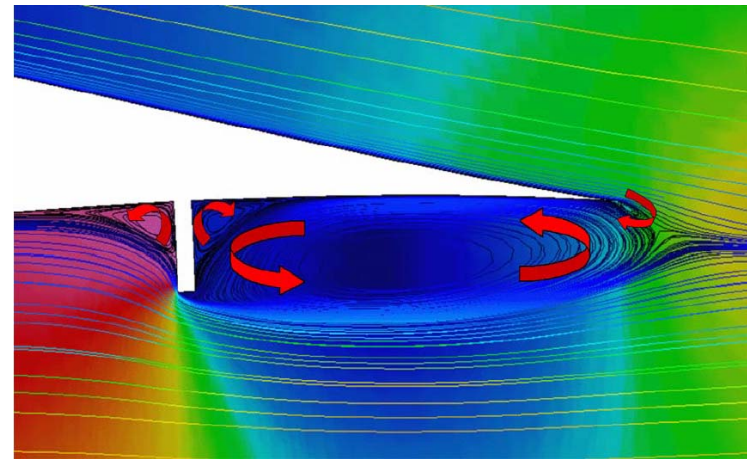
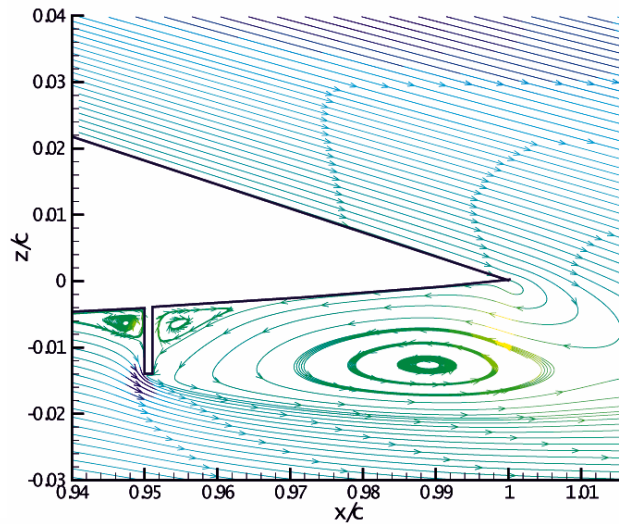


Advances Coming out of WindPACT and Blade Research

Passive devices



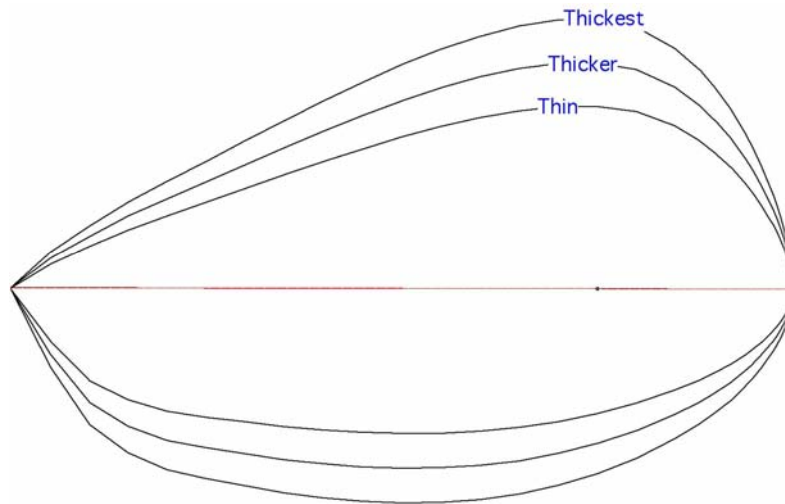
Active devices



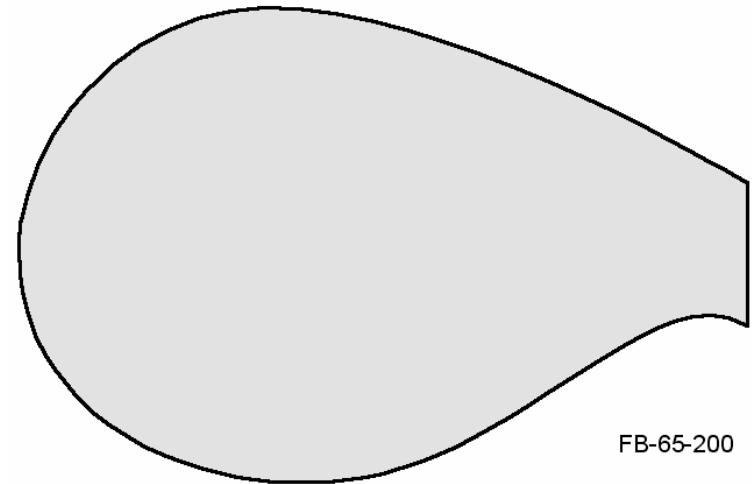


Advances Coming out of WindPACT and Blade Research

Very thick airfoils



Truncated airfoils



FB-65-200



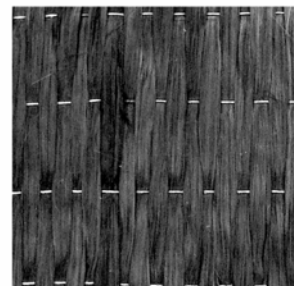
Advances Coming out of Materials Research and WindPACT

Carbon Coupon Tests

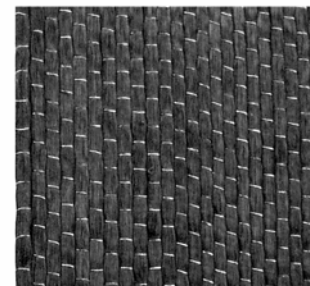


New Forms – Large & Medium Carbon Tows

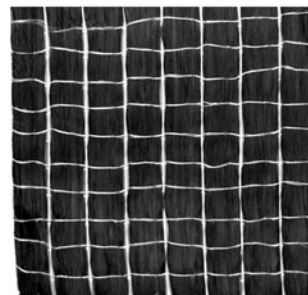
Zoltek UNI21



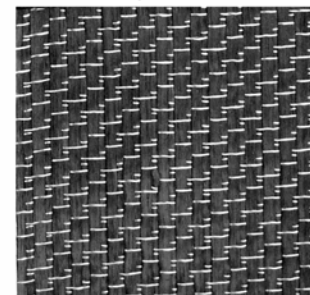
Zoltek UNI25 (XP33FBUD25)



Toray ACM - 13 - 2



Toray UT - 70 - 60

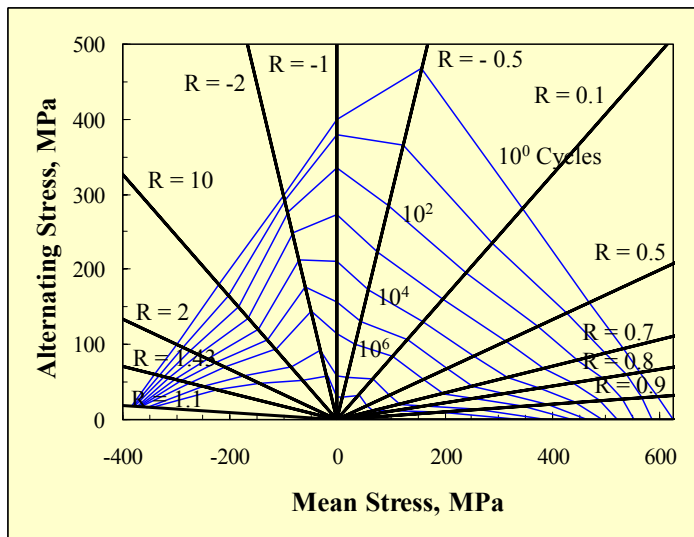


1 cm



Advances Coming out of Materials Research and WindPACT

Fatigue Characterization





Blade-Related Fabrication Contracts and New Technologies

- **WindPACT (BSDS Blade Fabrication)**
 - ♦ 9-m integrated blade design
 - ♦ Truncated airfoils
 - ♦ Constant thickness & width carbon spar cap
- **LWST Phase I System**
 - ♦ Clipper – Not a blade development (off-the-shelf, perhaps)
 - ♦ GE - Sub-scale carbon demonstration & full scale blade (carbon)
 - ♦ NPS – Possible blade development
- **LWST Phase II Components (\$2 million each)**
 - ♦ Knight & Carver – 25m - carbon & sweep twist
 - ♦ GE – subscale article - carbon, bend-twist, innovative internal architecture for off-shore blade
 - ♦ TPI – 44m with carbon and bend-twist

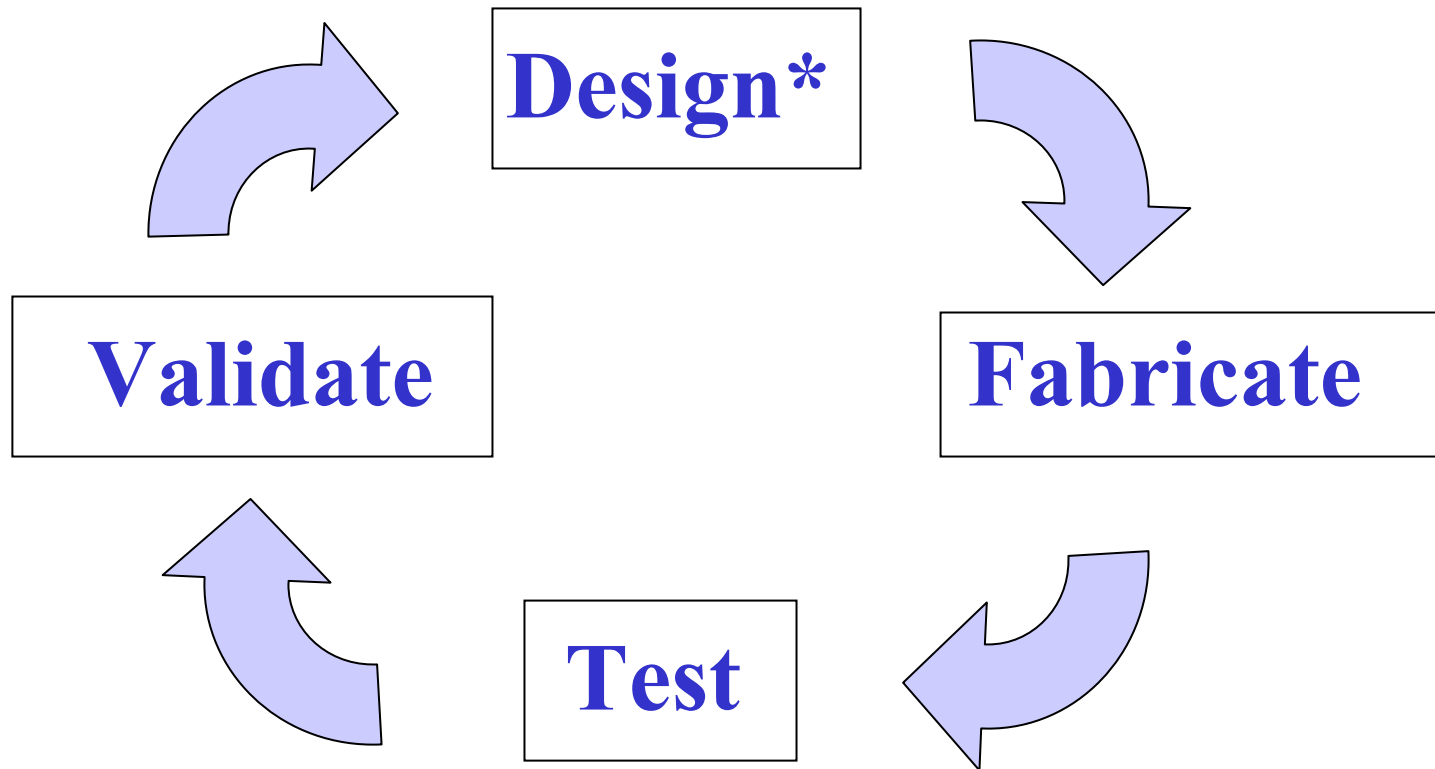


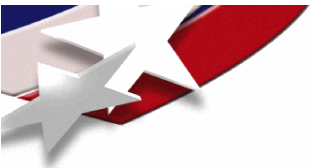
Blade-Related Contracts & New Technologies

- **Carbon-Hybrid Blade Developments (Enabling Research)**
 - ♦ CX-100 & TX-100 – carbon, bend-twist, constant spar cap thickness
- **SBIR (Carbon in Blades)**
 - ♦ GEC/TPI – 29m demonstrator with carbon, bend-twist
 - ♦ 3Tex – 3D braided materials
 - ♦ Wetzel – carbon, manufacturing process (details are proprietary)
- **DWT**
 - ♦ Applied Sciences – carbon & process (HCBMP)
 - ♦ Stoddard – new materials & process (RIM panels bonded to carbon spar)
 - ♦ Wetzel – 7m, carbon, bend-twist (details are proprietary)



Validation Loop for Design, Models & Manufacturing Process





CX & TX Testing Will Support Validation Loop

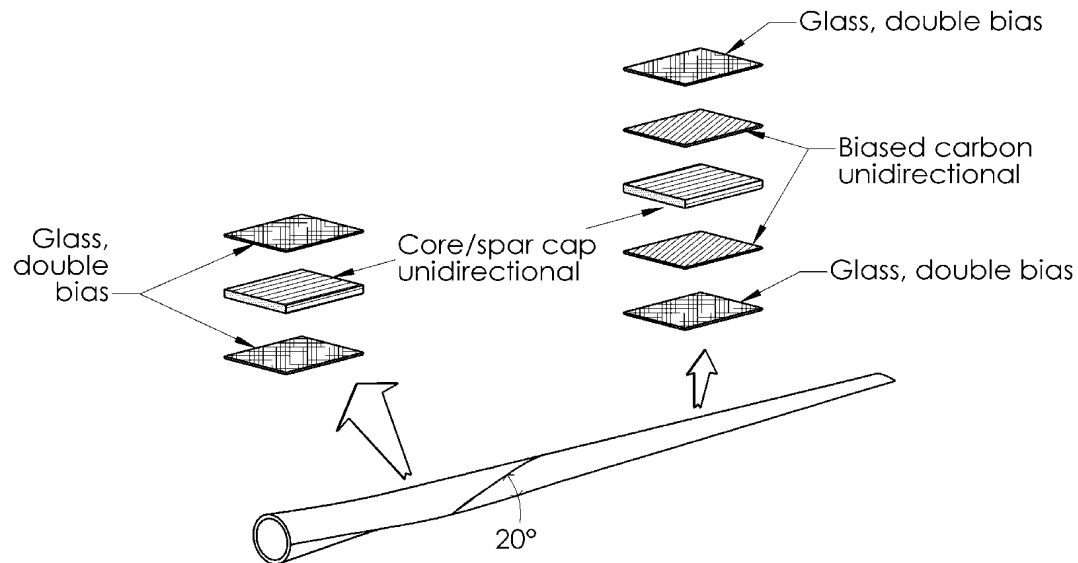
- **Basic Blade Mass Properties & CG Measurements at TPI Composites**
- **Detailed Blade Mass Properties Measurements at SNL**
- **Full Blade Modal Test (SNL, NREL & Bushland, TX)**
- **Full Blade Static Test (NREL)**
- **Full Blade Fatigue Test (NREL)**
- **NDT (SNL)**
- **Twist Measurements (TPI, NREL)**
- **Blade Loads Field Test (Bushland, TX)**
- **Power Curve Field Test (Bushland, TX)**



CX-100 & TX-100 Research Blades

- Both 9-m for flight testing at Amarillo
- GX-100 – glass baseline (paper only)
- CX-100 - carbon spar cap, glass skins & web, infusion, balsa core
- TX-100 – carbon fibers in skin @ 20° (triax) & glass spar cap, balsa core

TX-100 Design Concept to Induce Twist-Bend Coupling





CX-100 - Gel Coat in Mold





CX-100 Blade Lay-up & Root Build-up





Infusion Equipment & Shear Web (CX-100)





Spar Cap with Balsa and Stud Cavities (CX-100)





CX-100 Blade Shells





CX-100 Shells Ready for Bonding



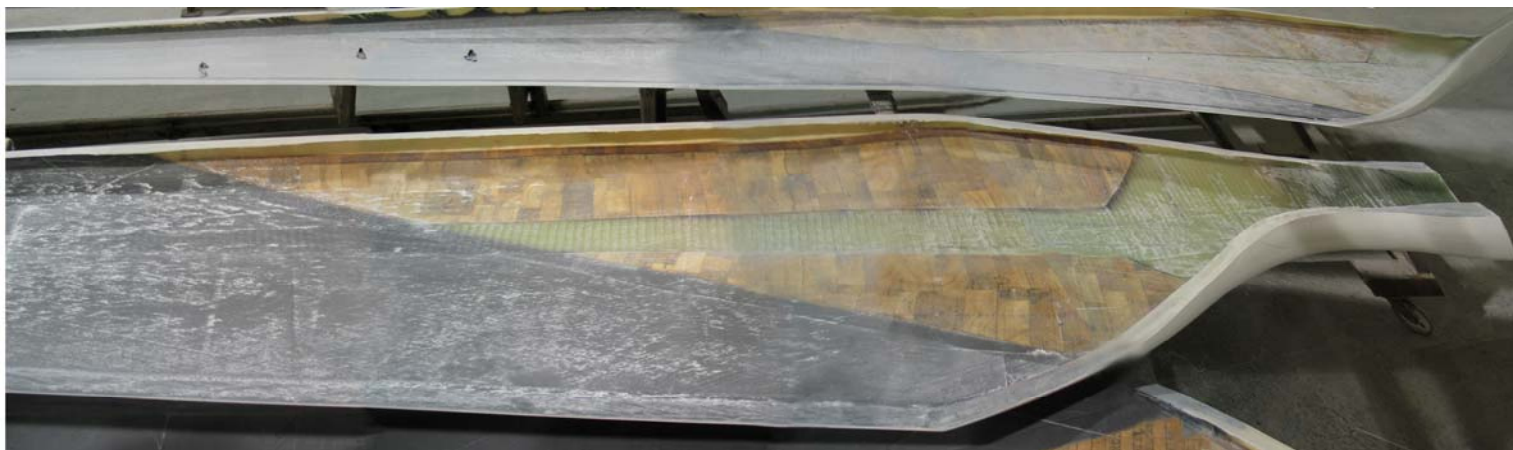


TX-100 Lay-up & Infusion





TX-100 Carbon Tri-ax & Glass Spar-Cap





Adios!!

